

hence it cannot have altered more than 0·23 vibration, for which the rust fully accounts. At the same time five other forks, of a large size and very different make, after having journeyed to America and back to be measured by Professor Mayer, have, according to Professor McLeod's measures, lost ·0015, ·165, ·0205, ·0285, and ·014 vibration respectively. The second fork was not so good as the rest, and may possibly have been slightly wrenched, as it had to be screwed in and out of a wooden holder. The other losses scarcely exceed errors of observation and differences of estimation of the effects of temperature.

The points to which I wish to draw attention are, the establishment of the acceleration of beats which take place in confined spaces, and the corroboration of Helmholtz's theory of the objective existence of partial tones, by means of beats of these partial tones, either with one another or with those of other compound tones.

II. "On the Lowering of the Freezing-Point of Water by Pressure." By JAMES DEWAR, M.A., F.R.S., Jacksonian Professor of Natural Experimental Philosophy in the University of Cambridge. Received June 10, 1880.

The Cailletet pump may be conveniently employed to observe the thermal effects of compression on solid and fluid substances. Before engaging in an investigation on this subject, it was necessary to test the apparatus, and especially the manometer. For this purpose it seemed, on theoretical grounds, that observations on the lowering of the freezing-point of water by pressure would be a severe test of the accuracy of the pressure gauge, and the constancy of the records of the thermo-junctions under pressure. I am not aware of any quantitative experiments on this subject having been made under high pressures. Sir William Thomson carried the proof of the accuracy of Professor James Thomson's great theoretical discovery to a pressure of 17 atmospheres.\* The experiments of Mousson ("Pogg. Annalen," 1858) were not of a quantitative character, being merely intended to show that ice at a temperature of  $-18^{\circ}$  C. might still be liquefied by the application of an enormous pressure. The following experiments appear to show that a convenient manometer for very high pressures, based on the observation of the freezing-point, may be easily constructed.

In all the following experiments the galvanometer, moving to the negative side, represents a cooling effect on the junction inside the

\* "The Effect of Pressure in Lowering the Freezing-Point of Water experimentally demonstrated." "Phil. Mag.," 1850.

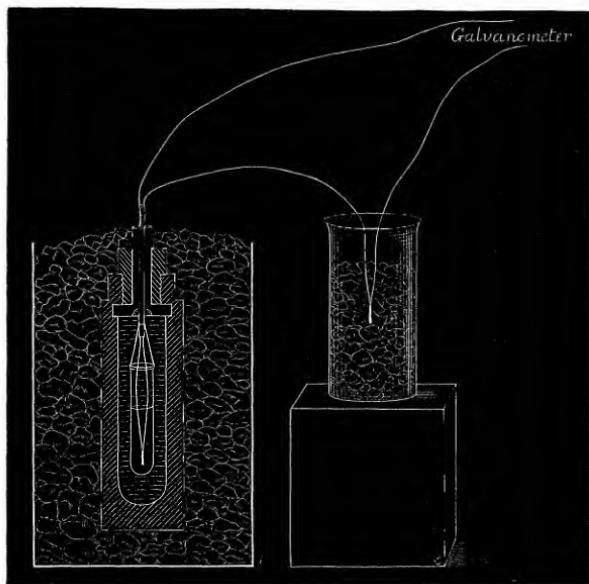
bottle. One division on the arbitrary scale represented about  $\frac{1}{12}$  of a degree C. Two thermo-junctions, made of iron-copper wires, insulated by a covering of marine glue, the junctions themselves being covered with a thin layer of gutta-percha dissolved in benzol, were employed in the experiments.

One junction was placed in the iron bottle, to record the effect of pressure under different circumstances, the other was kept in a beaker outside at the constant temperature of melting ice.

### *Series I.*

(Fig. 3 shows the general arrangement of bottle and thermo-junctions.)

FIG. 3.



A junction, fixed in a brass flange with marine glue, was frozen in a test-tube containing boiled water, and placed in the iron bottle of the Cailletet apparatus, surrounded with water at 0° C., the bottle itself being packed round with ice.

The pressure was increased by 25 atmospheres at a time. The galvanometer showed a deflection immediately after the pressure was applied, rapidly coming to rest, and it remained perfectly steady at the lower temperature as long as the pressure was maintained constant.

The following table gives the results of one of many series of experiments, which agreed very nearly. Pressures were recorded by a

metallic manometer which had been chequed on several occasions. The records of the first 25 atmospheres' pressure are not reliable.

Galvanometer zero +1.	Increase.
25 atmospheres = - 26 position on scale.....	17
50 , " = - 43 , " , " .....	19
75 , " = - 62 , " , " .....	20
100 , " = - 82 , " , " .....	18
125 , " = - 100 , " , " .....	20
150 , " = - 120 , " , " .....	22
175 , " = - 142 , " , " .....	21
200 , " = - 163 , " , " .....	22
225 , " = - 185 , " , " .....	18
250 , " = - 203 , " , " .....	20
275 , " = - 223 , " , " .....	20
300 , " = - 243 , " , " .....	

This represents a mean deflection of 19·7 on the scale, being 0·18 of a degree C. for 25 atmospheres, or a lowering of the freezing-point by 2°·1 C. for the total range of pressure. The mean reduction for one atmosphere of pressure is 0°·0072.

These experiments were afterwards repeated, with a stronger pump, to 700 atmospheres. Exactly the same mean deflection was observed, and the galvanometer moved with the same regularity.

### *Series II.*

The junction in the flange was placed in a piece of quill tubing, open at top and bottom, in order to insulate it from the sides of the iron bottle, and surrounded with water at 0° C. instead of ice, the iron bottle being afterwards packed, as before, in ice. On applying pressure a very slight decrease of temperature occurred, the whole deflection for 200 atmospheres being only about 4 divisions, or  $\frac{1}{25}$  of a degree C. This agrees with Joule's\* experiments on the compression of water about the same temperature.

### *Series III.*

A mixture of finely powdered ice and water was placed round the junction inside the bottle, which was, as usual, packed afterwards in ice. It will be seen, from the following set of readings, that the deflection was about the same as when the junction was frozen into a block of ice, the only difference being that, whereas the galvanometer in the first series assumed its new position immediately after the pressure was applied, the instrument now required from two to three minutes before coming finally to rest, the action being far more sluggish.

\* "On the Thermal Effects of Compressing Fluids." "Proc. Roy. Soc.," vol. ix, p. 496.

Pressure.	Position on Scale.	Difference.
Zero = +6.		
25 .....	- 17 .....	19
50 .....	- 36 .....	19
75 .....	- 55 .....	19
100 .....	- 74 .....	17
125 .....	- 91 .....	19
150 .....	- 110 .....	20
175 .....	- 130 .....	19
200 .....	- 149 .....	

Mean deflection for 25 atmospheres is 19·4 divisions of the scale.

#### *Series IV.*

Brine was placed round the junction in the bottle, the latter being afterwards packed in ice and salt, to reduce the temperature of the brine to  $-18^{\circ}$  C., the other junction being placed in ice and salt in a beaker outside the iron bottle. The junctions were then connected up with the galvanometer, and allowed to remain until the temperature became equalised :—

Atmospheres.	Position on Scale.	Increase.
Zero +85.		
25 .....	+ 98 .....	8
50 .....	+106 .....	9
75 .....	+115 .....	6
100 .....	+121 .....	7
125 .....	+128 .....	6
150 .....	+134 .....	4
175 .....	+138 .....	4
200 .....	+142 .....	

In this case a heating effect was produced, which seemed, however, to decrease as the pressure was increased. It represents an increase of  $\frac{1}{25}$  of a degree Centigrade for the whole 200 atmospheres.

#### *Series V.*

The junction in the flange was frozen into a solid block of ice as in Series I, and placed in the bottle, surrounded with brine at  $-20^{\circ}$  C., the whole apparatus packed in ice and salt. A very slight heating effect was produced, which only amounted to about  $1\frac{1}{2}$  divisions for 200 atmospheres.

#### *Series VI.*

These experiments were made with the junction frozen into a test-tube as in Series I, with mercury surrounding the test-tube instead of water. This gave exactly the same deflection of the galvanometer as when water was employed, only the experiment could not be carried

on for a long time, as the ice melted with considerable rapidity, from the heating of the mercury by compression.

*Series VII.*

As in several cases the junction that was placed inside the bottle, and which had been several times subjected to high pressures, appeared to be affected by the compression and worked somewhat irregularly, it was thought advisable to subject both the junctions to the same compression, so as to have them both under the same conditions. For this purpose both junctions were passed through the brass flange (fig. 1), being well insulated by marine glue, the one remaining outside of the test-tube in which the other was frozen.

FIG. 1.

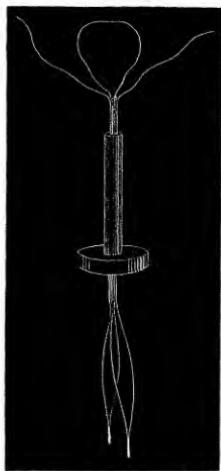


FIG. 2.



The results with ice were exactly the same as when one junction was placed outside of the bottle. Pressure still appeared to have an effect upon the junctions, as after one or two series of compression experiments they could be no longer relied upon, and worked very irregularly. The only way to obviate this difficulty was to prevent the junctions being submitted to pressure at all, and this was effected by soldering a stout iron tube (fig. 2), about  $\frac{1}{4}$  inch internal diameter, into the brass flange, which reached to about the centre of the bottle. The tube was closed at the bottom and contained a few cubic centimetres of alcohol, into which the junction was lowered from the outside. The part of the tube which went into the bottle was then frozen into a mass of ice, and the iron tube sustained all the interior pressure. The alteration of temperature was conveyed slowly through the iron to the junction.

This method worked exceedingly well, giving exactly the same results as before, the only drawback being that the action was very sluggish, the galvanometer taking about two minutes to come to rest after each addition of pressure. The above results seem to prove that the calculated value of the variation of the freezing-point of water, deduced from the observed difference of volume of ice and water, and the latent heat of fluidity at the melting-point under one atmosphere of pressure, is identical with the mean experimental value obtained from a series of observations extending to 700 atmospheres. From Clapeyron's formula we are thus entitled to infer that  $\frac{TV}{L} = \text{constant}$ , where T is absolute temperature, V the difference of volume of the two states, and L the latent heat of fluidity. If V is assumed to be approximately constant, then T varies as L. Thus the latent heat of ice diminishes as the freezing-point is lowered by pressure. This is in accordance with the deductions of Clausius\* from other considerations.

III. "On the Critical Point of Mixed Vapours." By JAMES DEWAR, M.A., F.R.S., Jacksonian Professor of Natural Experimental Philosophy in the University of Cambridge. Received June 10, 1880.

The following experiments regarding the behaviour of carbonic acid in presence of different vapours above the temperature of the critical point of the pure gas, were undertaken to ascertain if any optical discontinuity could be observed in such mixtures. As the object was intentionally a qualitative investigation, many of the pressure observations have been taken with the metallic manometer.

*The Liquefaction of Carbonic Acid in presence of other Bodies.*

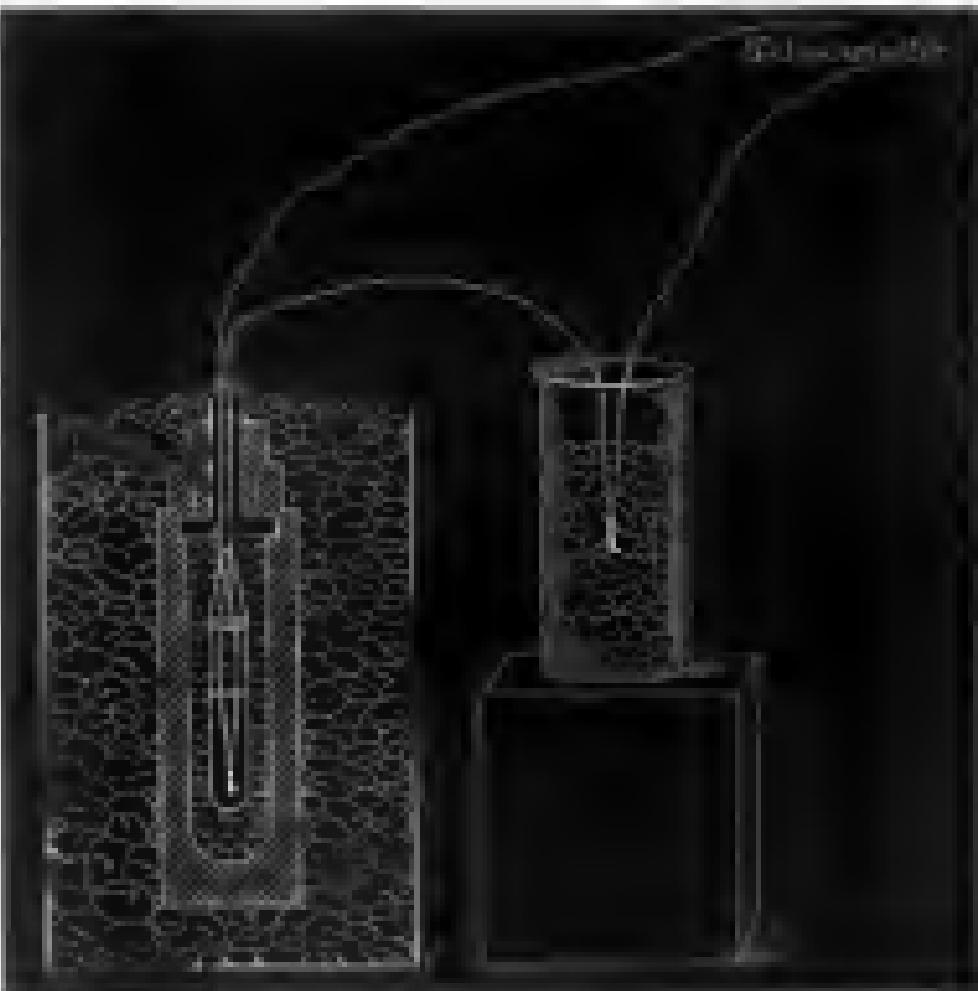
1. *Carbonic Acid and Bisulphide of Carbon.*

Carbonic acid liquefied in presence of a small quantity of bisulphide of carbon at a pressure of 49 atmospheres and a temperature of 19° C. It floated on the convex surface of the bisulphide, the line of separation being sharp and well defined.

At 35° C. liquid condensed on the surface of the bisulphide in the same way at a pressure of 78 atmospheres, at 40° C. it still appeared at 85 atmospheres, at 55° C. there seemed to be a distinct appearance of two liquids, and at 58° C. there was still the same apparent separation under a pressure of 110 atmospheres. Observed at 47° C. and a

\* "Phil. Mag." 1851.

FIG. 3.



# Fig. 1



